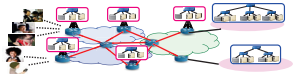
Multi-Cloud Global Application Delivery for Internet of Things and Smart Cities



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Keynote at The 2nd IEEE International Conference on Collaboration and Internet Computing (CIC), Pittsburgh, PA, Nov 1, 2016.

These slides and recording of this talk are available on-line at:

http://www.cse.wustl.edu/~jain/talks/adn_cic.htm or http://bit.ly/jain_cic

Overview

- Why Multi-Cloud?
  - 1. Internet of Things and Smart Cities
  - 2. Mobile Traffic Explosion: NFV
  - 3. Any Function Virtualization
  - 4. Mobile Edge Computing
- OpenADN Multi-Cloud Management
- Service Function Placement Problem

Trend: Smart Everything

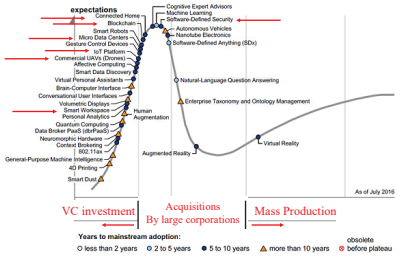
Smart Watch	Smart TV	Smart Car
Smart Health	Smart Home	Smart Kegs
Smart Space	Smart Industries	Smart Cities

What's Smart?

- Old: Smart = Can think ⇒ Computation
  = Can Recall ⇒ Storage
- Now: Smart = Can find quickly, Can Delegate
  ⇒ Communicate = Networking
- Smart Grid, Smart Meters, Smart Cars, Smart homes, Smart Cities, Smart Factories, Smart Smoke Detectors, …

Not-Smart Smart

Gartner Hype Cycle 2016



Ref: Gartner, "Hype Cycle for Emerging Technologies, 2016," July 2016, [subscribers only], gartner.com/document/3383817

IoT Business Opportunity

- $1.7 Trillion by 2020 - IDC
- $7.1 Trillion - Gartner
- $10-15 Trillion just for Industrial Internet – GE
- $19 Trillion – Internet of Everything - Cisco

Ref: http://www.forbes.com/sites/gilpress/2014/08/22/internet-of-things-by-the-numbers-market-estimates-and-forecasts/ http://www.forbes.com/sites/gilpress/2014/08/22/internet-of-things-by-the-numbers-market-estimates-and-forecasts/

A 7-Layer Model of IoT

Services	Energy, Entertainment, Health, Education, Transportation, …		
Apps and SW	SDN, SOA, Collaboration, Apps, **Clouds**	Security	Management
Analytics	Machine learning, predictive analytics, Data mining, …		
Integration	Sensor data, Economic, Population, GIS, …		
Interconnection	DECT/ULE, WiFi, Bluetooth, ZigBee, NFC, …		
Acquisition	Sensors, Cameras, GPS, Meters, Smart phones, …		
Market	Smart Grid, Connected home, Smart Health, Smart Cities, …		

ICT

A 7-Layer Model of Smart Cities

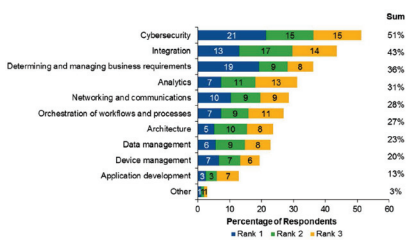
Services	Energy, Entertainment, Health, Education, Transportation, water, …		
Apps and SW	SDN, SOA, Collaboration, Apps, **Clouds**	Security	Management
Analytics	Machine learning, predictive analytics, Data mining, …		
Integration	Sensor data, Economic, Population, GIS, …		
Interconnection	DECT/ULE, WiFi, Bluetooth, ZigBee, NFC, …		
Acquisition	Sensors, Cameras, GPS, Meters, Smart phones, …		
Infrastructure	**Roads, Trains, Buses, Buildings, Parks, …**		

ICT

IoT is a Data ($) Mine

Ref: https://www.pinterest.com/iofficecorp/humor/

Top Inhibitors to the Adoption of the IoT



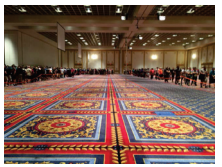
Ref: B. Lheurex, et al, "Survey Analysis: Users Cite Ambitious Growth and formidable Technical Challenges in IoT Adoption," Gartner Report #G00300127, March 2016,

Internet of Harmful Things

Imagine, as researchers did recently at Black Hat, someone hacking your connected toilet, making it flush incessantly and closing the lid repeatedly and unexpectedly.

Ref: http://www.computerworld.com/article/2486502/security0/worm-may-create-an-internet-of-harmful-things--says-symantec--take-note--amazon-.html

DEFCON 2015



IoT Security: Popular Approach

Ref: http://cloudtweaks.com/2011/08/the-lighter-side-of-the-cloud-the-migration-strategy/

Current IoT Security

- HP Study
  - 80% had privacy concerns
  - 70% lacked encryption
  - 60% had insecure updates
- Symantec Study:
  - 1/5th of Apps did not use SSL (Secure transfers)
  - None of the devices provided mutual (gateway) authentication
  - No lock-out/delaying measures against repeated attacks
  - Common web application vulnerabilities
  - Firmware upgrades were not encrypted

Ref: http://fortifyprotect.com/HP_IoT_Research_Study.pdf

Ref: M. Barcena and C. Wueest, "Insecurity in the Internet of Things," Symantec, March 2015,

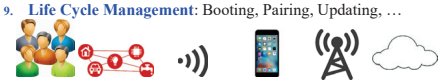
DEFCON 2015 (Cont)

- Hacking a Linux rifle
- Hacking smart safes
- Wirelessly steal cars
- Hack a Tesla
- Hack ZigBee
- Hacking IoT baby monitors
- Hacking FitBit Aria
- Cracking crypto currency
- Hack out of home detention
- Insteon's false security
- Hacking RFID, NFC
- DARPA Cyber Grand Challenge $2M

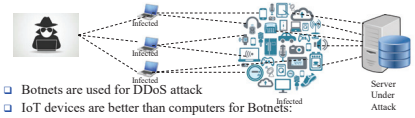
Ref: https://www.ethicalhacker.net/features/opinions/first-timers-experience-black-hat-defcon

Attack Surface

1. **Users**
2. **IoT Devices**
3. **IoT wireless access technology**: DECT, WiFi, Z-wave, …
4. **IoT Gateway**: Smart Phone
5. **Home LAN**: WiFi, Ethernet, Powerline, …
6. **IP and higher layer protocols**: DNS, Routers, …
7. **Cloud**
8. **Management Platform**: Web interface
9. **Life Cycle Management**: Booting, Pairing, Updating, …



IoT as an Attack Weapon



- Botnets are used for DDoS attack
- IoT devices are better than computers for Botnets:
  - Very high population compared to computers
  - Mostly unprotected with default passwords, open ports
  - Cameras, Routers, …
- Oct 21, 2016: Mirai bot used 62 default usernames and passwords to infect 380,000 IoT devices and then caused a DDoS attack on a popular DNS service dyn.com
  ⇒ Disabled many other sites for hours
- Mirai bot has made its source code public ⇒ Any kid can use it.
  ⇒ Xiangmai has recalled 10,000 webcams.

Ref: T. Green, "The secret behind the success of Mirai IoT botnets," Network World, Oct 27, 2016, http://www.networkworld.com/article/3136314

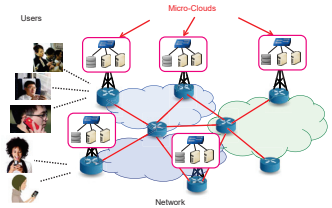
Trend: Micro-Cloud Computing

- Cloud computing was invented in 2006
- Then: Cloud = Large Data Center
  Multiple VMs managed by a cloud management system (OpenStack)
- Today: Cloud = Computing using virtual resources
  - μCloud = Cloud in a server with multiple VMs.
  - Each VM with Multiple Containers ⇒ Multiple Services

Networking App Market: Lower CapEx

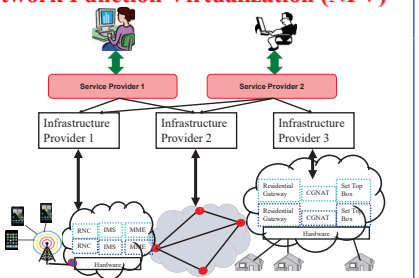
Trend: Mobile Edge Computing

- To service mobile users/IoT, the computation needs to come to edge ⇒ Mobile Edge Computing



Ref: Lav Gupta, Raj Jain, H. Anthony Chan, "Mobile Edge Computing - an important ingredient of 5G Networks," IEEE Softwarization Newsletter, March 2016, http://www.cse.wustl.edu/~jain/papers/mec16.htm

Network Function Virtualization (NFV)



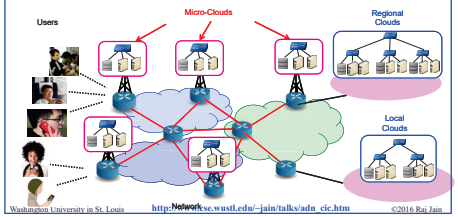
Ref: Raj Jain and Subharthi Paul, "Network Virtualization and Software Defined Networking for Cloud Computing - A Survey," IEEE Communications Magazine, Nov 2013, pp. 24-31, http://www.cse.wustl.edu/~jain/papers/net_virt.htm

Any Function Virtualization (FV)

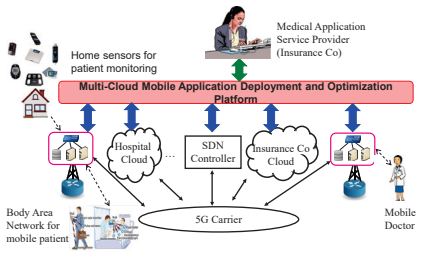
- "Network" function virtualization of interest to Network service providers
- But the same concept can be used by any other industry, e.g., financial industry, banks, stock brokers, retailers, mobile games, …
- Everyone can benefit from:
  - Functional decomposition of there industry
  - Virtualization of those functions
  - Service chaining those virtual functions (VFs) or **Apps**

Trend: Micro-Services

- All major applications, such as, Facebook, Netflix, etc. consist of a number of micro-services that are instantiated on demand on virtual machines

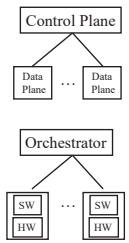


Mobile Healthcare Use Case



Software Defined Networking (SDN)

- SDN was invented in 2009
- Then: SDN:
  - Separation of control and data planes
  - Centralization of Control
  - Standard Protocol between the planes
- Now: Software Defined Everything (SDE) = **Disaggregation** of hw/sw
  - Commodity hardware
  - Software that runs on commodity hw
  - Open Source Software
    ⇒ Service industry
  - Controller replaced by Orchestrator
  - Centralization of policies

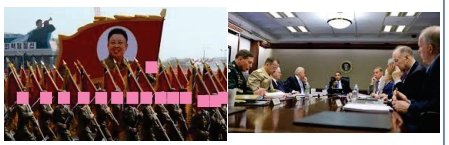


Ref: D. M Batista, G. Blair, F. Kon, R. Boutaba, D. Hutchison, R. Jain, R. Ramjee, C. Rothenberg, "Perspectives on software-defined networks: interviews with five leading scientists from the networking community" Journal of Internet Services and Applications 2015, 6:22, http://www.cse.wustl.edu/~jain/papers/jisa15.htm

Separation vs. Centralization

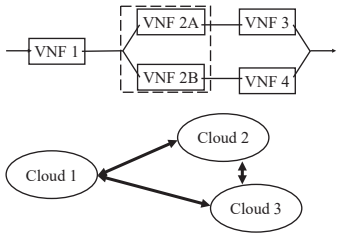
Separation of Control Plane

Centralization of Policies



Micromanagement is not scalable

Service Function Placement Problem



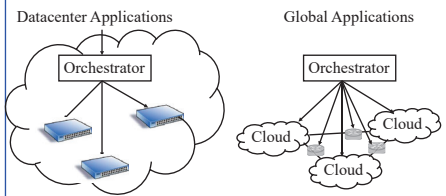
Ref: Deval Bhamare, Raj Jain, Mohammed Samaka, Aiman Erbad, "A Survey on Service Function Chaining," Journal of Network and Computer Applications, Sep 2016, 19 pp, http://www.cse.wustl.edu/~jain/papers/jnca16.htm

Challenges in Service Placement

- **Delay constraints**
- **WAN links bottleneck:** Need to model link queues
- **Complexity**: NP-complete ⇒ Need efficient heuristics
- **Affinity:** VNF1 and VNF2 should be co-located
  - Significant communication exchanges
  - Duplicate memory pages in VMs (same OS and Libraries)
- **Anti-Affinity**: VNF1 and VNF2 should not be placed on the same physical server.
  - CPU-intensive applications
  - VMs belonging to different users in a cloud may cause security risk such as cross-VM attacks
  - Duplicate VMs used to improve fault tolerance and availability

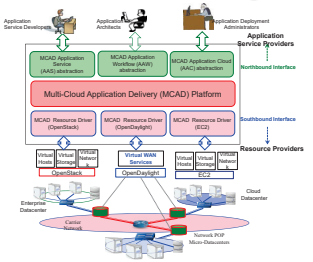
Software Defined Multi-Cloud

- Orchestrating devices to Orchestrating Clouds



Ref: Subharthi Paul, Raj Jain, Mohammed Samaka, Jianli Pan, "Application Delivery in Multi-Cloud Environments using Software Defined Networking," Computer Networks Special Issue on cloud networking and communications, December 2013, http://www.cse.wustl.edu/~jain/papers/comnet14.htm

OpenADN Multi-Cloud Management



Ref: Lav Gupta, Raj Jain, Mohammed Samaka, "Analysis of Application Delivery Platform for Software Defined Infrastructures," International Journal of Communication Networks and Distributed Systems, 2016, Vol. 5, http://www.cse.wustl.edu/~jain/papers/ijcnds16.htm

Summary

1. Value of IoT is in the data it produces. Privacy and Security are the key issues.
2. Clouds are getting smaller, Carriers and enterprises moving to clouds, Internet of things are leading to clouds everywhere ⇒ multi-cloud applications.
3. SDN is about orchestration and centralization of policy. Not about separation of control and data planes.
4. Software Defined Multi-Cloud Orchestration: Our Multi-cloud application management system (MCAD) allows policy-based deployment and management of multi-cloud applications.
5. Service function placement problem is NP complete. Challenges included delay constraints, WAN Link bottlenecks, and affinity

Acronyms

ATM	Asynchronous Transfer Mode
ECN	Explicit congestion notification
EFCI	Explicit Forward Congestion Indication
FECN	Forward Explicit Congestion Notification
GB	Gigabyte
IEEE	Institution of Electrical and Electronic Engineering
IETF	Internet Engineering Task Force
IoT	Internet of Things
IP	Internet Protocol
IRTF	Internet Research Task Force
ITU	International Telecommunications Union
LAN	Local Area Network
LTE	Long Term Evolution
MHz	Mega Hertz
OpenADN	Open Application Delivery Networking
SDN	Software Defined Networking

Acronyms (Cont)

- TCP Transmission Control Protocol
- TV Television
- VM Virtual Machine
- WAN Wide Area Network
- WiFi Wireless Fidelity
- WiMAX Worldwide Interoperability for Microwave Access

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